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ABSTRACT

Results of two experiments support the finding of developmental change in the role of representation in perspective-taking tasks. Experiment 1, which involved 80 first-grade students with a mean age of 6.5 years, crossed task characteristics and response modes. Subjects either imagined an observer's movement around a fixed array or imagined an array rotating on its vertical axis. They responded by either selecting an array model showing the observer's view or naming an item in the array which would occupy a specified position. Findings of experiment 1 differed markedly from results of previous research, particularly in the difficulty of the observer movement task with the item naming response at all degrees of rotation. In experiment 2, the task performance of 20 third-grade students in the two observer movement conditions replicated previous findings of Huttenlocher and Presson (1973, 1979). Comparisons of the data from experiments 1 and 2 revealed a significant interaction of grade and condition: first graders had markedly greater difficulty with observer movement problems with item questions than did third graders. Results are discussed. An 88-item reference list is appended. (RH)

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Developmental Changes in Children's Ability to Solve Spatial
Transformation Problems

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Developmental Changes in Children's Ability to Solve Spatial
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A classic study in developmental psychology is Piaget and Inhelder's Three Mountains Task (1948/67), the findings of which show that children up to the age of 9 or 10 cannot accurately predict what another observer in a different position will see when they view an array of objects. Young children often respond incorrectly, generally by building or selecting the view from their own perspective.

Piaget and Inhelder made two claims based upon these data. One was that children making egocentric responses do not understand that other observers see things differently. However, several studies have documented that children as young as 2 years do realize that other people see something different than they do. Other researchers have found that a variety of factors--such as familiarity and number of response choices--can lead to earlier or later success on perspective-taking tasks. Flavell and his associates have suggested that spatial perspective-taking demands both Level 1 skills--knowledge of what other people can see in general--and Level 2 skills--the computational ability to work out exactly what another observer sees when an array contains more than one object. They have not described the nature of this computational ability, however, the developmental change may well be one in systems for representing spatial location. This leads into Piaget and Inhelder's second major claim.

Piaget and Inhelder proposed that success on the

perspective-taking tasks requires the use of a representational system called projective space, a system which is acquired after topological representation. Topological space is a primitive system for representing spatial location based upon parts of figures or their patterns. Under this system, location is coded in terms of relationships of proximity, continuity and enclosure. Projective space begins when the child no longer views objects in isolation. The child is able to consider relations between objects, either one object to other objects or self to other objects, by projecting lines from one object to the others (Piaget & Inhelder, 1948/67).

Huttenlocher and Presson (1973, 1979) have conducted a series of studies addressing the role of spatial representation on spatial transformation. An important finding coming out of this research is that young children do not find all kinds of tasks involving changes in spatial location equally difficult. In their 1979 study with third graders, these researchers used four different spatial transformation tasks. One is the classic Piagetian task--i.e., subjects are asked to imagine observer movement around a fixed array and to respond by selecting a picture showing the observer's view. (Hereinafter this condition will be referred to as observer movement with appearance question. It is No. 1 in Table 1.) A second task requires the subjects once again to imagine observe movement around a fixed array. However, they are asked to respond by naming which item in the array would occupy a specified position with respect to the observer. The third task, called array rotation with

appearance question, asks subjects to imagine the array rotating on its axis and to respond by picking a picture showing the observer's view of the rotated array. Lastly, in the array rotation with item question task subjects are asked to imagine the array rotating on its axis and once again to name which item in the array would occupy a specified position with respect to the observer.

The findings of this study show that the classic Piagetian task (Condition No. 1) was very difficult for eight year olds and that array rotation with item questions (Condition No. 4 in Table 1) was also fairly difficult (see Table No. 2). In contrast, array rotation with appearance questions and observer movement with item questions (Conditions No. 2 and 3 in Table 1) were quite easy for the third graders, and there were fewer egocentric errors on the latter two tasks (Huttenlocher & Presson, 1979).

In attempting to explain these results, Huttenlocher and Presson (1973, 1979) and Huttenlocher and Newcombe (1984) suggested that the observed pattern of difficulty would be found if subjects coded the location of objects in the array individually in relation to nearby external landmarks rather than internally with respect to each other--i.e., representing the array as a unit.

Presson (1982) found that adults show the same pattern of results. Thus, it seems logical that developmental changes in the role of representation on these tasks must occur prior to age 8, if they occur at all. The purpose of the present studies was to explore the role of representation by replicating the Huttenlocher and Presson study with first graders.

There are at least two conceivable outcomes to our studies. One possibility is that there are no developmental differences in the role of spatial representation, and our first graders will perform similarly to our third graders, although possibly at a lower level overall. Another possibility is that Piaget and Inhelder's theory will be supported. In the latter case, one would predict 6 year olds will do poorly on both of the observer movement tasks, although they may be able to do well on array rotation with appearance questions. In fact, our data support the claim of developmental change in the role of representation in perspective-taking tasks.

In Experiment 1 we included 80 subjects with a mean age of 6.5 years. Twenty were randomly assigned to each of the four conditions. The experimental array consisted of 1.5" symmetric shapes of four distinct colors: a blue cube, magenta pyramid, green ball and yellow star (see Figure 1). These shapes were familiar to the children, many of whom were learning about geometric shapes in their classes. Half-scale models were used as response alternatives. Each child had four practice trials, during which incorrect responses were corrected. The children received unlimited time to memorize object locations between each of the 16 test trials. Trials were counterbalanced by degree of rotation: 0, 90, 180 and 270 degrees.

Results

We found a dramatic difference from the results of prior research. If you look at the percentages of errors in Table 2 (right side), the first graders did very badly in general and

much worse than Huttenlocher and Presson's third graders on the observer movement with item question task (73% vs. 20%). Performance does not differ from chance at any degree of rotation. The 6 year olds performed similarly on the array rotation with item question and observer movement with appearance question tasks (54% and 48% errors, respectively). They actually did better on the classic Piagetian task than the third graders despite an overall difficulty with observer movement tasks. They were quite successful on the array rotation with appearance question task (20%). This is supported statistically by an analysis of variance, which showed significant main effects of movement type and question type. There was no interaction between these two factors.

There was a significant interaction between degree of rotation, movement type and question type, with 180 degrees being easiest in the observer movement with appearance question task, 90 degrees significantly more difficult in the observer movement with item question task and 270 degrees significantly more difficult in the array rotation with item question task. Array rotation with appearance questions was quite easy at all degrees of rotation. (See Figure 2) Most importantly, the interaction pattern found by Huttenlocher and Presson (1979) with 8 year olds does not appear at any degree of rotation with our 6 year olds. the most striking finding in the data is the difficulty of observer movement with item questions at all degrees of rotation since 8 year olds showed quite good performance on this task.

We also examined the types of errors subjects made (see Table 3). Three types of errors are possible: egocentric,

random and reversal (i.e., choosing either the item in the position opposite the correct response or the array showing the view from the opposite side).

Chi square tests on the proportions of errors for both of the observer movement conditions showed egocentric errors predominated at all degrees of rotation. On the other hand, for the array rotation conditions egocentric errors were frequently less common than expected by chance. Errors were either random or, in the case of appearance questions at 90 degrees, systematic reversals.

To ensure that these findings were not due to a subtle change in materials or procedure rather than to developmental change, we conducted a second experiment using third graders, 10 in each of the two observer movement conditions. We chose these two conditions rather than all four because this is where the major contrasts occurred.

The results of the second experiment are closely comparable to those of Huttenlocher and Presson. If you look at Columns 5 and 6 in Table 2, the percentages of errors are nearly identical in both conditions.

Finally, we compared the data from Experiments 1 and 2 by doing an analysis of variance on the numbers of errors in the two observer movement conditions for first and third graders. The results showed a significant interaction of grade and condition--first graders had markedly greater difficulty on observer movement problems with item questions than did third graders. This interaction further supports the likelihood of developmental

change in the ability to solve observer movement problems.

Discussion

While the most efficient way to solve spatial transformation tasks is to encode the array internally as a unit such that one has a mental representation of it upon which to perform transformations, it is apparent from the data that our subjects were not encoding spatial location in this sophisticated manner. Nor is the problem due to a general difficulty with spatial transformation tasks, since performance on array rotation with appearance questions is already excellent by first grade. Furthermore, the problem cannot be attributed to difficulty in understanding or answering item questions since the children did quite well on item questions when no transformation was required.

While a number of hypotheses have been suggested to explain the developmental change, none of them can account for the bulk of the data. The following hypothesis seems to be the most plausible. It is that first graders encode all the object locations and their own location externally but not in relation to any overall framework of landmarks, as third graders do. Rather, first graders code the location of each object and their own location using a framework of landmarks which does not always overlap with the framework used for other positions. The 6 year olds' piecemeal encoding would allow for success on array rotation with appearance questions tasks if at least one object was encoded with respect to the same landmarks as the child's own position. Poorer performance on the observer movement tasks with appearance questions would be found due to the requirement for use of a common framework for three rather than two locations in

this case (i.e., a hypothetical position in addition to their own position and one object).

Piecemeal encoding would also lead to poorer performance on item questions than appearance questions. Success on array rotation tasks would occur only when the child's position was encoded with respect to the same framework of landmarks as the object which was the correct item. Similarly, success on observer movement tasks would occur only when the hypothetical position and the target item were encoded using the same framework. In neither case would encoding just any one of the four objects lead to successful performance.

Third graders do well with item questions. However, they still do poorly on observer movement with appearance questions, the classic Piagetian task. This would occur if the children were encoding all the locations with respect to a common framework but were experiencing difficulty with the latter task because it is a two-step, rather than one-step, operation.

This hypothesis closely coincides with Piaget and Inhelder's claim that success on perspective-taking tasks requires the use of projective representation of space in the following sense. Piaget and Inhelder state that by 7 years of age or slightly earlier the child is able to construct straight lines by "aiming" along a trajectory and putting his or herself in line with the two other objects to be linked by the straight line. Thus by 6.5 years on average it is not surprising that our subjects could use external landmarks to encode locations. However, as we found with first graders' use of common frameworks, it may be that our

younger subjects do not use the same projections for all objects in the array, thus making it difficult for them to accurately predict spatial transformations under all conditions. In this respect our data points out the role of projective space in perspective-taking tasks.

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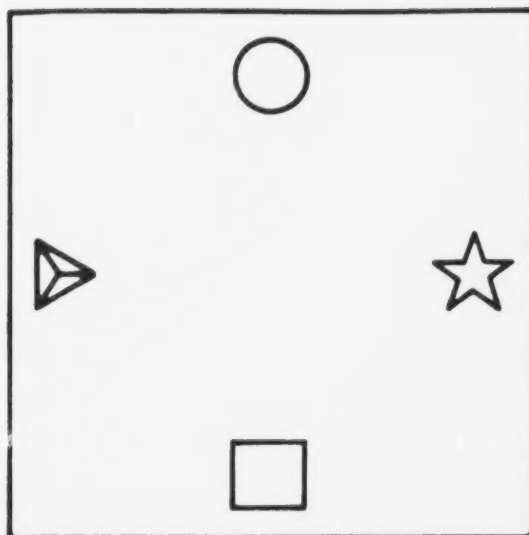
Table 1

Explanation of Task Conditions

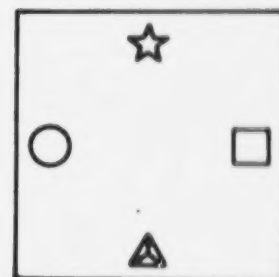
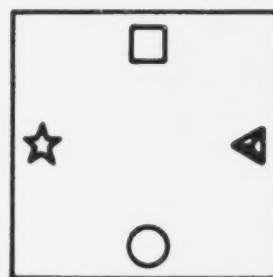
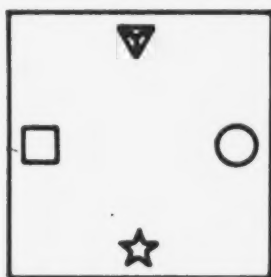
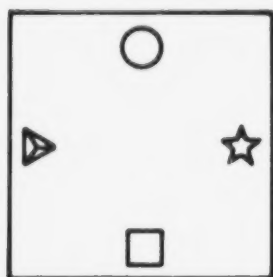
- 1) Observer Movement with Appearance Question (Piagetian task):
Task--Imagine observer movement around fixed array
Response mode--select array model showing observer's view
- 2) Observer Movement with Item Question:
Task--Imagine observer movement around fixed array
Response mode--name item which would occupy specified position
- 3) Array Rotation with Appearance Question:
Task--Imagine array rotating on its axis
Response mode--select array model showing observer's view
- 4) Array Rotation with Item Question:
Task--Imagine array rotating on its axis
Response mode--name item which would occupy specified position

• FIG. 1

Display



Appearance Question



Item Question

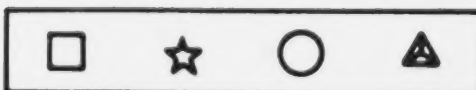
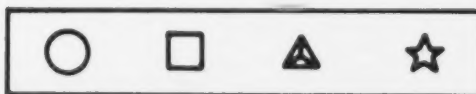


Table 2
Percentages Incorrect

	Nontransformation trials			Transformation trials		
Observer Movement	Grade 1	Grade 3	H&P	Grade 1	Grade 3	H&P
Appearance Question	15	3	4	48	62	56
Item Question	23	0	8	73	26	20
Array Rotation						
Appearance Question	1	-	6	20	-	15
Item Question	13	-	9	54	-	32

Table 3
Percentages of Error by Condition and
Degree of Rotation for First Graders¹

		Viewer Rotation		Array Rotation	
		AQ	IQ	AQ	IQ
		²		³	
0:	Reversal (33%)	42 (5)	44 (8)	--	50 (5)
	Random (67%)	58 (7)	56 (10)	--	50 (5)
		³		³	
90:	Reversal (33%)	24 (11)	14 (9)	76 (13)	38 (13)
	Random (33%)	26 (12)	29 (19)	12 (2)	25 (12)
	Egocentric (33%)	50 (23)	58 (38)	12 (2)	26 (9)
		³		³	
180:	Reversal/Egocentric (33%)	70 (16)	77 (40)	0	36 (11)
	Random (67%)	30 (7)	23 (12)	100 (14)	64 (21)
		³		³	
270:	Reversal (33%)	15 (7)	12 (7)	39 (7)	37 (24)
	Random (33%)	11 (5)	23 (14)	50 (9)	45 (29)
	Egocentric (33%)	74 (34)	65 (39)	11 (2)	18 (12)

¹ Raw numbers of errors are in parentheses.

² Chance expectations are in parentheses.

³ Not significantly different from chance.